Design and Testing of Photon Tagger Readout Electronics

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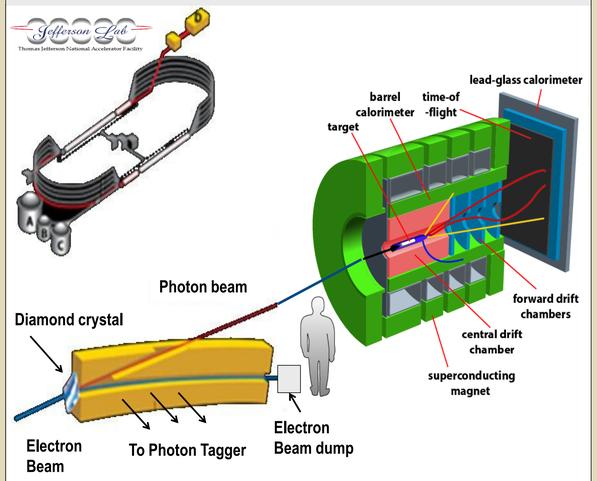
Abstract

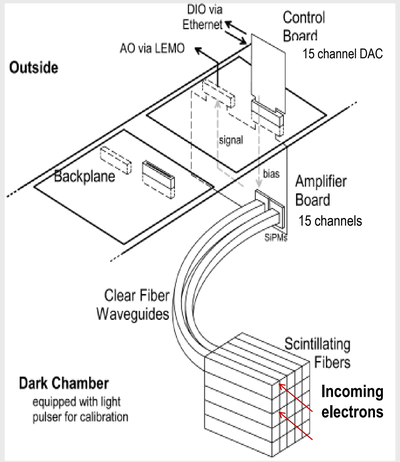
We are developing the electronics for the readout of signals from Silicon Photomultipliers (SiPMs) for a high energy photon tagger for the GlueX experiment at the Thomas Jefferson National Lab. These electronics are designed to amplify the signals from the SiPMs as well as provide bias voltages for each SiPM and to monitor important environmental parameters. We have modified the initial design to improve the signal quality of the amplified signal and have built a pulse generator to test the circuits. The signals from the updated prototype have been measured using a pulse generator and cosmic rays as input signals. We are now constructing the final set of tagger electronics to be used in the experiment.

GlueX



The GlueX experiment is designed to explore the properties of the strong force that confines quarks and gluons inside hadrons (e.g. protons, neutrons). GlueX will search for a new class of hadrons called “exotic mesons”, and map out their spectrum. Predicted to exist according to numerical studies of QCD, exotic mesons can be visualized as a quark and an anti-quark bound by a vibrating elastic string of gluons. To produce these exotic mesons, high energy photons are directed onto protons in a liquid hydrogen target, which produce new hadrons by shaking quark-antiquark pairs out of the vacuum and scattering them from the proton target. The photon beam is produced by passing a high energy electron beam through a thin bremsstrahlung target made of diamond. The post-bremsstrahlung electrons are then analyzed in a magnetic spectrometer called a tagger. This project concerns the readout of the tagging detector.

Photon Tagging Hodoscope Readout

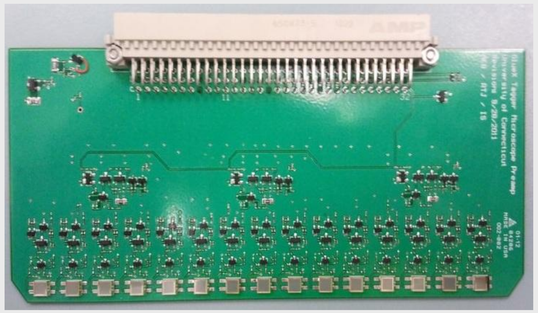


The purpose of the photon tagging hodoscope is to measure the energy and timing of the electrons exiting the diamond crystal so that the energy of the bremsstrahlung photons can be determined individually using energy conservation. The photon tagger consists of a light-sealed dark chamber containing scintillating fibers packed together in a square array as shown in the figure. Clear waveguide fibers carry the light produced in the scintillators to a nearby readout system consisting of Geiger-mode photodiode arrays called Silicon Photomultipliers (SiPMs). The rest of the readout consists of pre-amplifiers and digitizers that record the signals, and control electronics. The 5x100 segmentation of the scintillator provides excellent momentum resolution of 4MeV for a photon energy of 9GeV, 0.05% in the photon energy. The photon energy, E_{photon}, is computed from the electron momentum, $p_{e,final}$, measured in the spectrometer through the following relation, where the electrons are assumed to be ultra-relativistic.

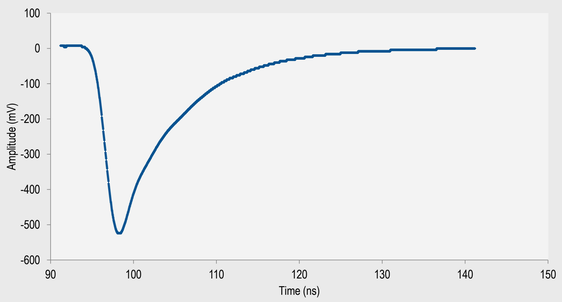
$$E_{photon} = (p_{e,initial} - p_{e,final})c$$

Our group designed custom electronics for the readout:

- Custom pre-amplifier board, pictured on the right
- Each pre-amplifier board houses 15 SiPMs
- Pre-amplifiers designed to enable
  - 200ps time resolution
  - individual photon counting pulse height resolution
  - low power consumption, radiation-resistant (gamma radiation)

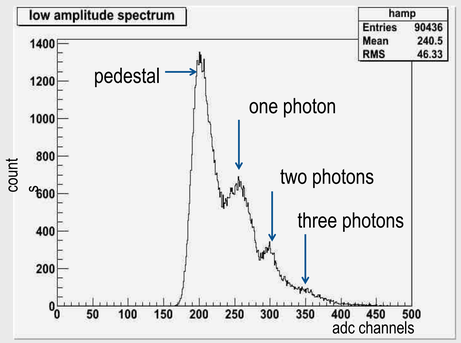


Signal Shape



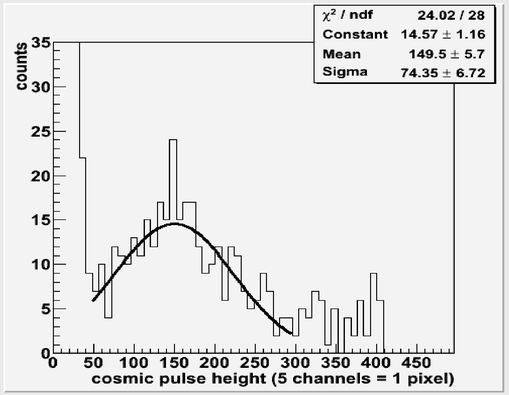
- One SiPM biased, others left unbiased
- Averaged over 128 samples
- Rise time is about 2ns, fall time about 12.5ns

Dark Rate Test



- Single biased SiPM in high gain mode
- Every 50 channels corresponds to 10mV
- Each pixel in high gain corresponds to 10mV, as predicted

Cosmic Ray Test



- We expect $\frac{8000\gamma}{MeV} \cdot \frac{1.7MeV}{cm} \cdot 0.25cm \cdot 0.05 \cdot 0.20 \cdot 0.9 \cong 30$ photoelectrons per cosmic, where
  - 1.7 is the loss per distance traveled in plastic
  - 0.25 is the thickness of the fiber
  - 0.05 is the capture fraction of the fiber
  - 0.20 is the detector efficiency
  - 0.9 is the attenuation of the fiber
- 200 pe / tag required
- We have 300 pe / tag for longitudinal tracks

We are currently working to produce the entire final set of electronics consisting of 34 preamplifiers, 17 bias control boards and 6 backplanes. The PCB drawings have been updated to reflect circuit changes and adhere to dimension requirements and have been submitted for fabrication. Once these are received we will perform quality assurance tests before installing the electronics at JLab.

References

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3. Hamamatsu Multi-Pixel Photon Counter http://jp.hamamatsu.com/resources/products/ssd/pdf/s10362-33_series_kapd1023e05.pdf
4. UConn Particle and Nuclear Group http://zeus.phys.uconn.edu/wiki/index.php/Student_Projects_in_Nuclear_Physics

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